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(54) Solid-state colour imaging apparatus.

(57) Colour filters are arranged in rows (ℓ_1 to ℓ_8) and columns with a vertical recurrence cycle of four picture elements. The filters in every first row (ℓ_1, ℓ_5) and in every third row (ℓ_3, ℓ_7) are all the same colour, e.g. transparent (W) or spectrally weighted to create a luminance signal. In each second row (ℓ_2, ℓ_6) there is a first set of colour filters (G, Mg) for generating a first colour difference signal component modulated with a two-element horizontal repetition cycle. In each forth row (ℓ_4, ℓ_8) there is a second set of colour filters (Ye', Cy') for generating a second colour difference signal component modulated with a two-element horizontal repetition cycle. The use of filters of the same colour throughout the first and third rows avoids the generating of large vertical colour errors in the output signal of a change-coupled device arrangement providing luminance and colour difference signals from the picture elements, even in the presence of sharp vertical edges which are un-correlated between adjacent rows of elements.

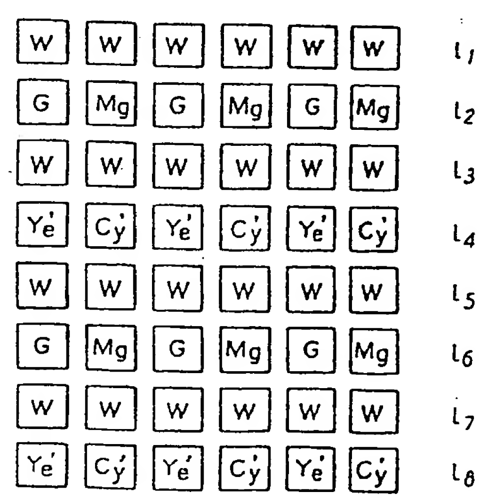

FIG. 7

SOLID-STATE COLOR IMAGING APPARATUS

This invention relates to a solid-state color imaging apparatus.

An interline transfer CCD imaging element (hereinbelow, abbreviated to "IL-CCD imaging element") comprises a plurality of picture elements arrayed regularly in both a horizontal direction and a vertical direction. Vertical CCD registers transfer, in the vertical direction, signal charges which are photoelectrically converted by and stored in the picture elements. At the ends of the vertical column, a horizontal CCD register transfers them in the horizontal direction to an output portion.

The IL-CCD imaging element is capable of two sorts of read-out operations which are a frame storage operation in which the signal charges stored in the picture elements are read out during every frame period, and a field storage operation in which they are read out during every field period. The field storage operation requires a half of the frame storage time, and gives a lesser feeling of afterimage. For this reason, the development of a single-plate color imaging device for effecting the field storage operation is being promoted.

In color imaging by the use of the IL-CCD imaging element, the color separated images of a subject are formed by color filters. The color separated images are picked up by the IL-CCD imaging element. The output signals of the IL-CCD imaging element are processed, thereby to obtain chrominance and luminance signals.

A conventional IL-CCD imaging apparatus having a conventional color filter has a disadvantage, to be described below. The signal of each horizontal line is a sum of the signal charges obtained by independently and spatially sampling the two adjacent picture elements in

the vertical direction and is not constituted by a single horizontal line signal. This causes a very large vertical color error in the output signal of the conventional imaging apparatus when the apparatus picks up a subject having a vertical repetition frequency equal to one half of the number of the vertical picture elements, that is, a sharp vertical contour portion having no vertical correlation between two adjacent horizontal picture element rows.

It is, therefore, an object of this invention to provide a solid-state color imaging apparatus capable of producing faithful output signals even when a sharp vertical contour portion having no vertical correlation is picked up.

According to to this invention, there is provided a solid-state color imaging apparatus having an improved color filter. The color filter has a reccurrence cycle of four picture elements in the vertical direction. In first and third rows, the same filters are arrayed for generating the same signal component from each picture element. In a second row, a first set of color filters are arrayed for generating a first color difference signal component modulated with a predetermined number of picture elements forming one cycle in the horizontal direction. In a fourth row, a second set of color filters are arrayed for generating a second color difference signal component modulated with a predetermined number of picture elements forming one cycle in the horizontal direction.

The features and advantages of this invention will be understood from the following detailed description of preferred embodiments, taken in conjunction with the accompanying drawings, wherein:

Fig. 1 is a schematic view of an interline transfer CCD imaging element;

Fig. 2 is a diagram schematically showing the readout of signal charges in the interline transfer CCD imaging element in a field storage mode;

Fig. 3 is a schematic partial plan view showing the arrangement of color filters and the mutual relationships between the color filters and picture elements in a conventional color imaging apparatus;

Fig. 4 is a diagram schematically showing the outputs of respective color signals from an interline transfer CCD imaging element which is furnished with the color filters in Fig. 3;

Fig. 5 is a diagram showing a color difference vector;

Fig. 6 is a schematic block diagram of a single-plate type color imaging device;

Fig. 7 is a schematic partial plan view showing the arrangement of color filters and the mutual relationships between the color filters and picture elements in accordance with a first embodiment of this invention;

Figs. 8 and 9 are diagrams each showing the spectral characteristics of color filters of Fig. 7;

Fig. 10 is a diagram schematically showing the outputs of respective color signals from the first embodiment;

Fig. 11 is a diagram showing a color difference vector; and

Fig. 12 is a schematic partial plan view showing the arrangement of color filters and the mutual relationships between the color filters and picture elements in accordance with a second embodiment of this invention.

First, a conventional CCD color imaging apparatus will be described with reference to Figs. 1 through 6.

A conventional IL-CCD imaging element (Fig. 1) comprises picture

elements 1 arrayed regularly in a horizontal direction and a vertical direction. Vertical CCD registers 2 transfer, in the vertical direction, signal charges which are photoelectrically converted by and stored in the picture elements 1. At the ends of the vertical columns, a horizontal CCD registers 3 transfers them in the horizontal direction, to an output portion 4. Arrows are used in Fig. 1 to indicate the transfer directions of the signal charges.

Fig. 2 schematically illustrates the field storage operation. Rows in the horizontal direction are successively marked $\ell 1$, $\ell 2$, $\ell 3$, $\ell 4$, --- $\ell 8$, --- begining with a certain row. In odd-numbered fields, the signal charges are first transferred to the vertical CCD registers 2 from the picture elements correspondang to lines or rows $\ell 2$, $\ell 4$, $\ell 6$, $\ell 8$, ---. The signal charges corresponding to one picture element are substantially shifted by the shift operation of each vertical CCD register 2. Further, the signal charges are transferred to the vertical CCD registers 2 from the picture elements corresponding to lines or rows $\ell 1$, $\ell 3$, $\ell 5$, $\ell 7$, ---. As a result, the signal charges of the picture elements corresponding to lines or rows $\ell 2$, $\ell 4$, $\ell 6$, $\ell 8$, --- are respectively added with the signal charges of the picture elements corresponding to lines or rows $\ell 1$, $\ell 3$, $\ell 5$, $\ell 7$, --- in the vertical CCD registers 2. The signal charges of each of the lines or rows $\ell 1 + \ell 2$, $\ell 3 + \ell 4$, $\ell 5 + \ell 6$, $\ell 7 + \ell 8$, --- are added and used as a signal for one horizontal period.

In even-numbered fields, the combinations of the rows of the picture elements in the horizontal direction which are to be added in the vertical CCD registers 2 are changed into lines or rows $\ell 2 + \ell 3$, $\ell 4 + \ell 5$, $\ell 6 + \ell 7$, ---. The combinations of the two respectively adjacent rows in the vertical direction are changed every field, in this manner, thereby

performing an interlaced operation.

In color imaging by the use of the IL-CCD imaging element, as stated above, the color separated images of a subject are formed by color filters. The output signals of the IL-CCD imaging element are processed, to obtain chrominance signals and luminance signals.

Fig. 3 is a schematic partial plan view showing the color arrangement of the color filters as used in a conventional single-plate color imaging apparatus of the field storage operation also showing the mutual relationships between the color filters and the picture elements.

Referring to Fig, 3, the plurality of picture elements 1 are regularly arranged in the horizontal direction and in the vertical direction. The color filters are formed on the respective picture elements 1. The letters Ye, Cy, Mg and G indicate the color filters for yellow, cyan, magenta and green, respectively. The yellow color filter transmits red and green light, the cyan color filter transmits blue and green light, and the magenta color filter transmits red and blue light. The color filters are arrayed with two picture elements forming one cycle in the horizontal direction and with four picture elements forming one cycle in the vertical direction. The rows in the horizontal direction are identified as lines or rows $\ell 1$, $\ell 2$, $\ell 3$, ---, $\ell 8$, --- successively from a certain row. From the left toward the right in the horizontal direction, filters Ye and Cy are alternately and repeatedly arranged in the horizontal rows $\ell 1$ and $\ell 5$; filters Mg and G are alternately arranged in the next rows $\ell 2$ and $\ell 6$; filters Ye and Cy in the next $\ell 3$ and $\ell 7$; and filters G and Mg in the next rows $\ell 4$ and $\ell 8$.

Fig. 4 is a diagram schematically showing the magnitude of the outputs of the color signals from the respective picture elements, formed

with the aforementioned color filters, in the case of the field storage operation. These color signals result from an array of filters, as shown in Fig. 3. The letters B, G and R respectively denote a blue signal, a green signal and a red signal, the ratio of which are set at 1:1:1. As illustrated in Fig. 4, when the output signals are averaged, R + 3/2G + B is obtained. This combination of signals is used as the luminance signal. Color difference signals are alternately (every one horizontal line) superposed as modulation components (R − 1/2G)cos wt and (B − 1/2G)cos wt with two picture elements forming one cycle in the horizontal direction. Here, w denotes an angular frequency which corresponds to the cycle of two picture elements. The output signals $S(\ell_1 + \ell_2)$ and $S(\ell_3 + \ell_4)$ of lines or rows $\ell_1 + \ell_2$ and $\ell_3 + \ell_4$ are indicated by the following equation.

$$\begin{aligned} S(\ell_1 + \ell_2) &= (B + 2G + R - B\cos wt + R\cos wt)/2 \\ &\quad +(B + G + R + B\cos wt + R\cos wt - G\cos wt)/2 \\ &= B + 3/2G + R + (R - 1/2G)\cos wt \\ S(\ell_3 + \ell_4) &= (B + 2G + R - B\cos wr + R\cos wt)/2 \\ &\quad +(B + G + R - B\cos wt - R\cos wt + G\cos wt)/2 \\ &= B + 3/2G + R - (B - 1/2G)\cos wt \end{aligned}$$

The NTSC color television signal can be constituted by using (B + 3/2G + R) as the luminance signal, and the modulation components (R − 1/2G) and (B − 1/2G) as two orthogonal color difference signals as shown in Fig. 5. The signals of the even-numbered fields are similarly constituted, because the signals $S(\ell_2 + \ell_3)$ and $S(\ell_4 + \ell_5)$ are same as the signals $S(\ell_1 + \ell_2)$ and $S(\ell_3 + \ell_4)$, respectively.

Fig. 6 is a schematic block diagram of the single-plate type of color imaging device. The output signal of the IL-CCD imaging element 6

The spectral characteristics of the color filters in Fig. 7 are illustrated in Figs. 8 and 9.

Fig. 10 is a diagram schematically showing the magnitude of the outputs of the solor signals taken from the respective picture elements formed with the aforementioned color filters in the field storage which corresponds to Fig. 7. As illustrated in Fig. 10, the average value of the output signals is 3/2(B + G + R), which is used as the luminance signal. In the output signal of lines or rows $\ell_1 + \ell_2$, a first color difference signal component 1/2(R + B) – 1/2G, i.e., 1/2(Mg – G) is superposed as a modulation component 1/2(Mg – G)cos wt, with two picture elements forming one cycle in the horizontal direction. In the output signal of lines or rows $\ell_3 + \ell_4$, a second color difference signal component 1/2(R – B) orthogonal to the (Mg – G) axis is superposed as a modulation component 1/2(R – B)cos wt, with two picture elements forming one cycle in the horizontal direction. Therefore, the output signals $S(\ell_1 + \ell_2)$ and $S(\ell_3 + \ell_4)$ of the lines or rows $\ell_1 + \ell_2$ and $\ell_3 + \ell_4$ are indicated by the following equations:

$$S(\ell_1 + \ell_2) = (2B + 2G + 2R)/2 + (B + G + G\cos wt - Mg\cos wt)/2$$
$$= 3/2(B + G + R) - 1/2(Mg - G)\cos wt$$
$$S(\ell_3 + \ell_4) = (2B + 2G + 2R)/2 + (B + R + R\cos wt - B\cos wt)/2$$
$$= 3/2(B + G + R) + 1/2(R - B)\cos wt$$

The NTSC color television signal can be constituted by using the base-band component 3/2(B + G + R) as the luminance signal, and the modulation components 1/2(Mg –G) and 1/2(R – B) as the color difference signals orthogonal to each other as shown in Fig. 11.

In the even-numbered fields, the output signals $S(\ell_2 + \ell_3)$ and $S(\ell_4 + \ell_5)$ are indicated by the following equations:

$$S(\ell 2 + \ell 3) = 3/2(B + G + R) - 1/2(Mg - G)\cos wt$$

$$S(\ell 4 + \ell 5) = 3/2(B + G + R) + 1/2(R - B)\cos wt$$

The output signal from the solid-state imaging apparatus of the first embodiment can be converted to the NTSC color television signal by the apparatus shown in Fig. 6 so modified that modulation axes in the balanced modulation circuit 16 are rotated to meet with the (Mg - G) and (R - B) axes shown in FIg. 11.

A second embodiment shown in Fig. 12 is identical to the first embodiment except that the filters W for the odd-numbered rows are substituted by filters Y having a spectral characteristic close to that of the luminance signal of the NTSC color television signal, that is, for transmitting green, half-blue and half-red (G + 1/2B + 1/2R).

The output signals of respective horizontal scanning lines in the field storage operation are indicated by the following equations:

$$S(\ell 1 + \ell 2) = B + 3/2G + R - 1/2(Mg - G)\cos wt$$

$$S(\ell 3 + \ell 4) = B + 3/2G + R + 1/2(R - B)\cos wt$$

$$S(\ell 2 + \ell 3) = B + 3/2G + R - 1/2(Mg - G)\cos wt$$

$$S(\ell 4 + \ell 5) = B + 3/2G + R + 1/2(R - B)\cos wt$$

In the first and second embodiments, the color difference signal component is not included in alternate ones of the horizontal rows (i.e., odd-numbered rows), but in only the other rows (i.e., even-numbered rows), whereby the vertical color error is not generated in the color difference signal in the output signal even when the horizontal picture elements in the adjacent rows have no vertical correlation. Thus, the color difference signal included in the output signal from the color imaging apparatus according to this invention is formed from the single horizontal picture element row, thereby to provide the color television signal without generating the vertical color error.

CLAIMS

1. A solid-state colour imaging apparatus comprising rows and columns of colour filters arranged with a recurrence cycle of four picture elements in the vertical direction, characterised in that, within each four row unit ($\ell_1 - \ell_4$; $\ell_5 - \ell_8$), the same colour filters are arranged in the first and third rows (ℓ_1, ℓ_3) for generating the same signal component from all the elements in those rows, a first set of colour filters is arranged in the second row (ℓ_2) for generating a first colour difference signal component modulated with a predetermined number of picture elements forming one cycle in the horizontal direction, and a second set of colour filters is arranged in the forth row (ℓ_4) for generating a second colour difference signal component modulated with a predetermined number of picture elements forming one cycle in the horizontal direction.

2. An apparatus according to claim 1, characterised in that the colour filters of the first and third rows (ℓ_1, ℓ_3) are transparent (W).

3. An apparatus according to claim 1, characterised in that the colour filters of the first and third rows (ℓ_1, ℓ_3) are spectrally weighted to pass a luminance signal (Y).

4. An apparatus according to claim 1, 2 or 3, characterised in that the colour filters of the second row (ℓ_2) are alternately green and magenta (G, Mg) or spectrally weighted green and magenta whereas the colour filters of the fourth row (ℓ_4) are alternately yellow and cyan or spectrally weighted yellow and cyan (Ye', Cy').

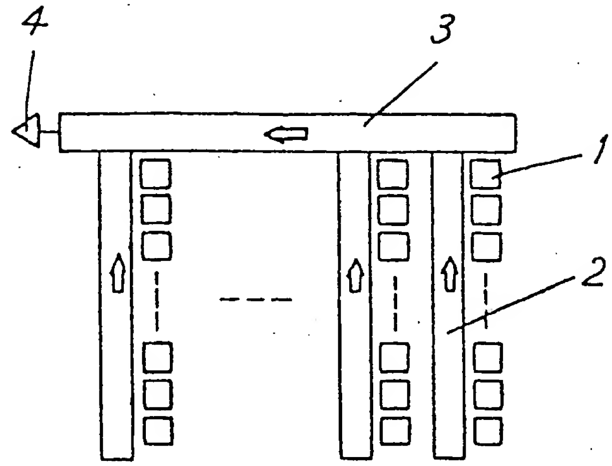

FIG. 1

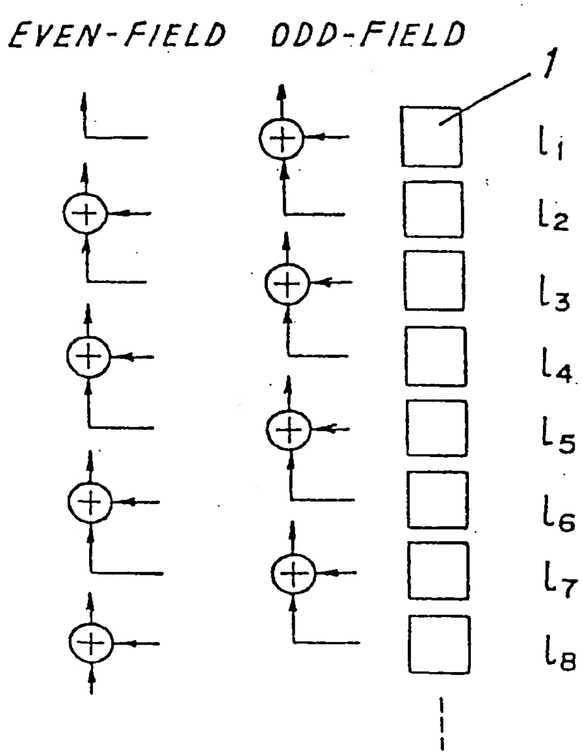

FIG. 2

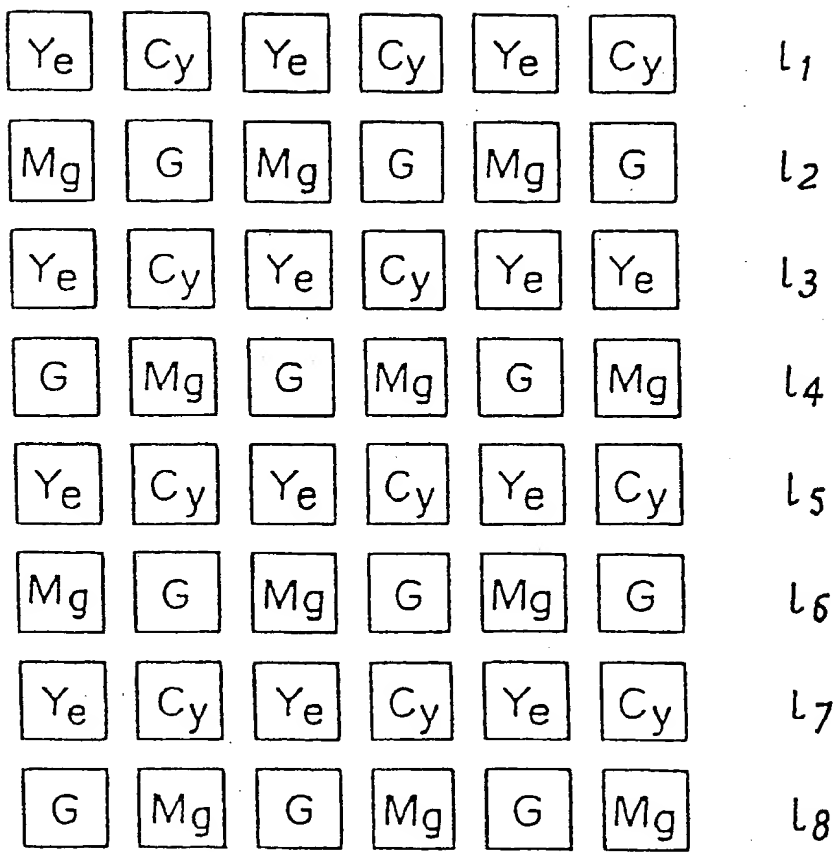
Ye Cy Ye Cy Ye Cy l_1
Mg G Mg G Mg G l_2
Ye Cy Ye Cy Ye Ye l_3
G Mg G Mg G Mg l_4
Ye Cy Ye Cy Ye Cy l_5
Mg G Mg G Mg G l_6
Ye Cy Ye Cy Ye Cy l_7
G Mg G Mg G Mg l_8

FIG. 3

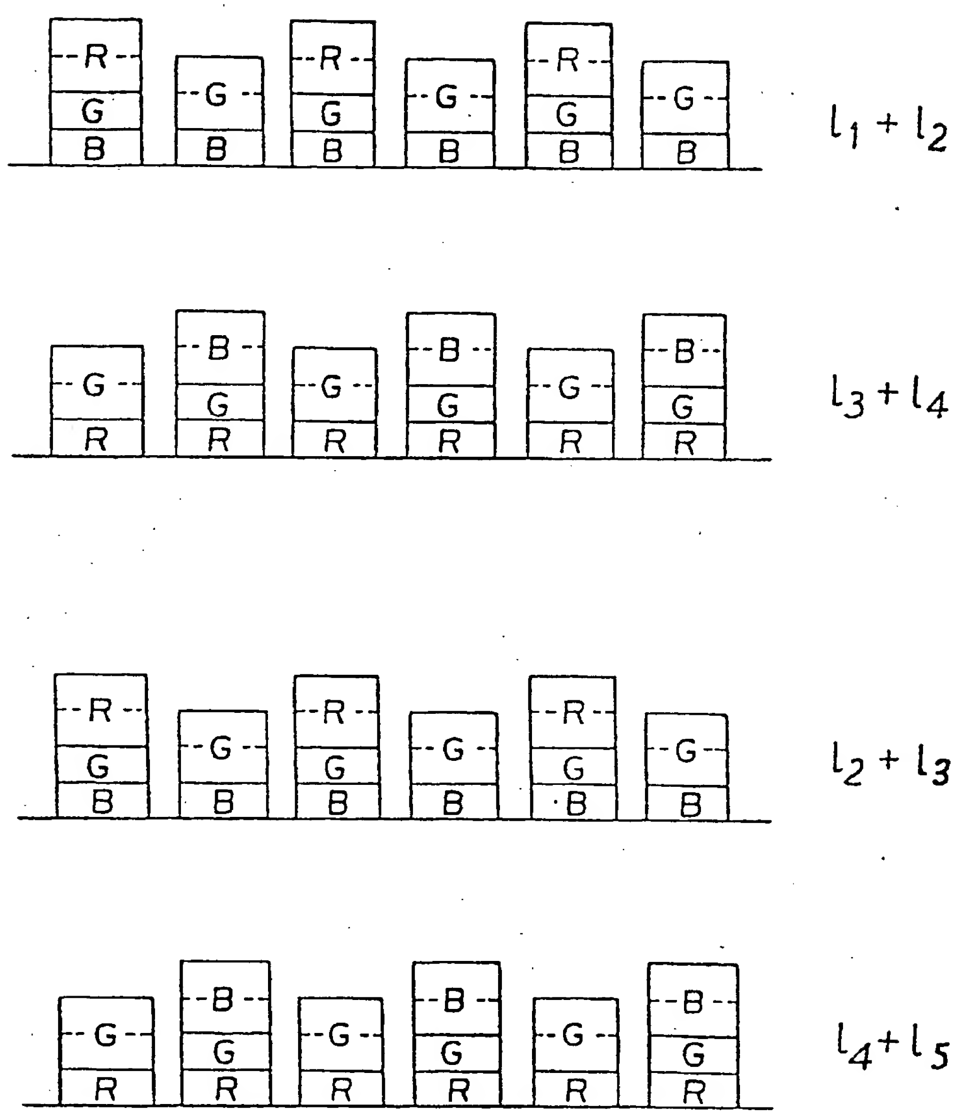

FIG.4

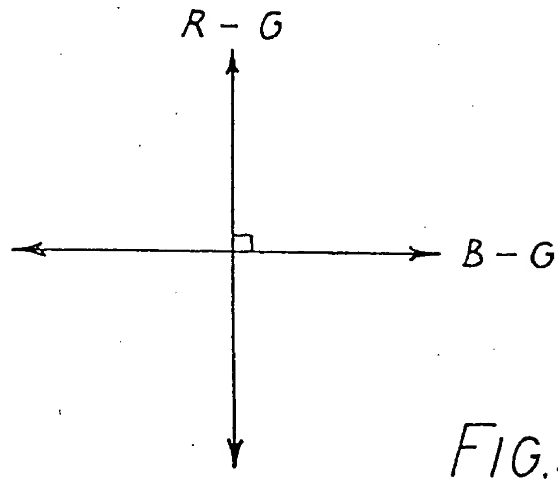

FIG.5

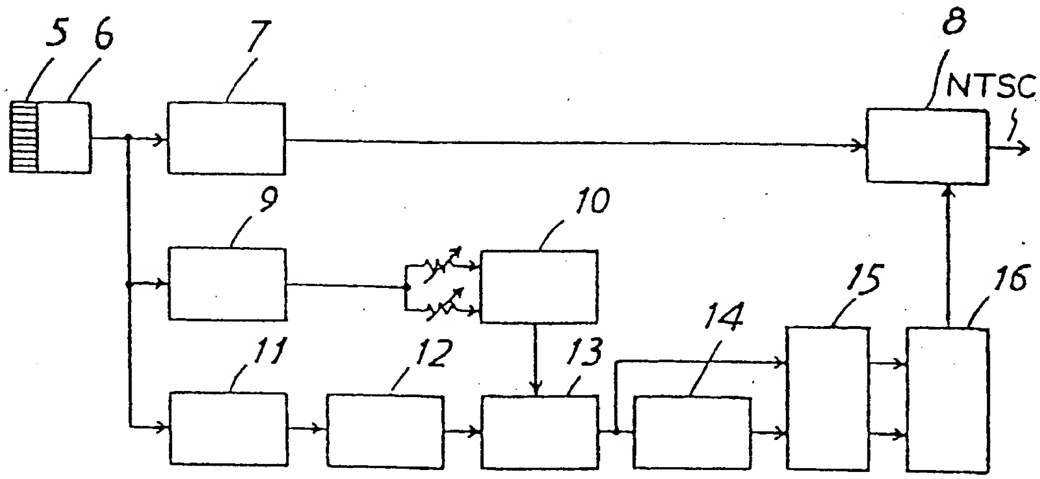

FIG.6

W	W	W	W	W	W	l_1
G	Mg	G	Mg	G	Mg	l_2
W	W	W	W	W	W	l_3
Ye'	Cy'	Ye'	Cy'	Ye'	Cy'	l_4
W	W	W	W	W	W	l_5
G	Mg	G	Mg	G	Mg	l_6
W	W	W	W	W	W	l_7
Ye'	Cy'	Ye'	Cy'	Ye'	Cy'	l_8

FIG. 7

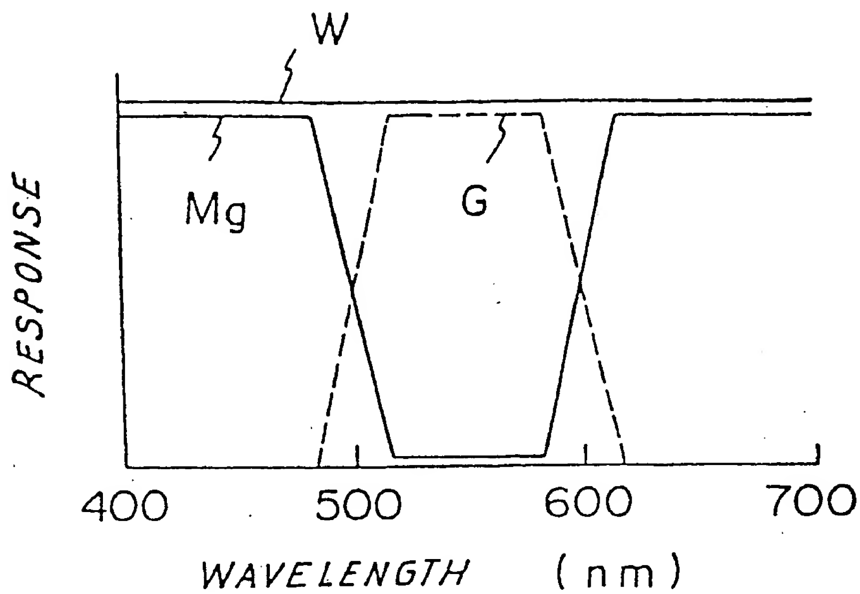
W
Mg
G
RESPONSE
400
500
600
700
WAVELENGTH (nm)

FIG. 8

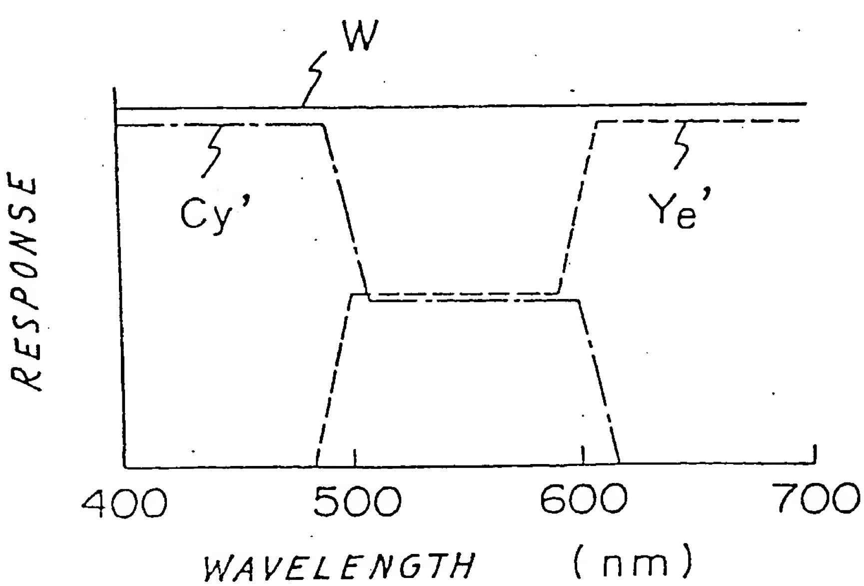
W
Cy'
Ye'
RESPONSE
400
500
600
700
WAVELENGTH (nm)

FIG. 9

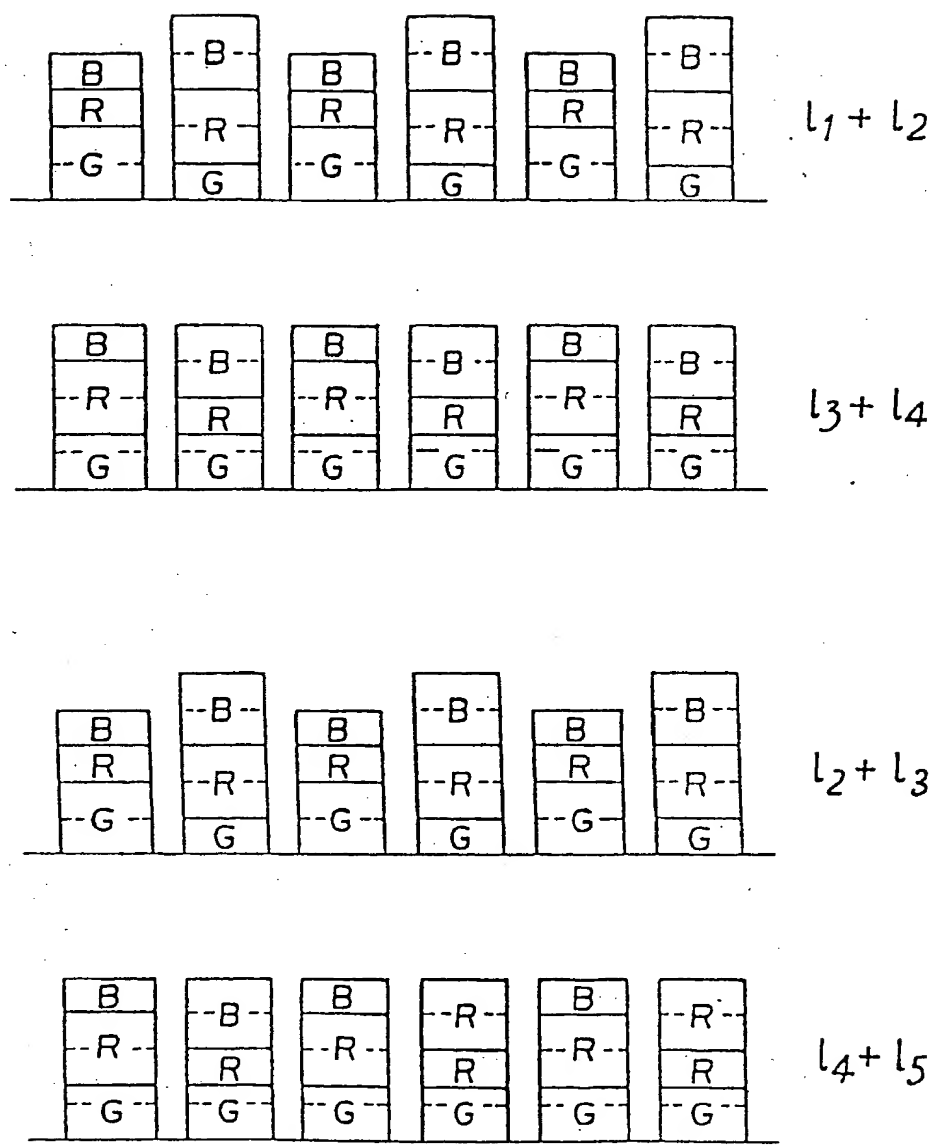

FIG.10

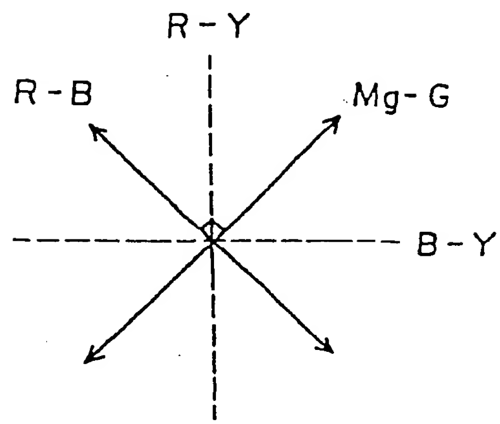
R - Y
R - B
Mg - G
B - Y

FIG. 11

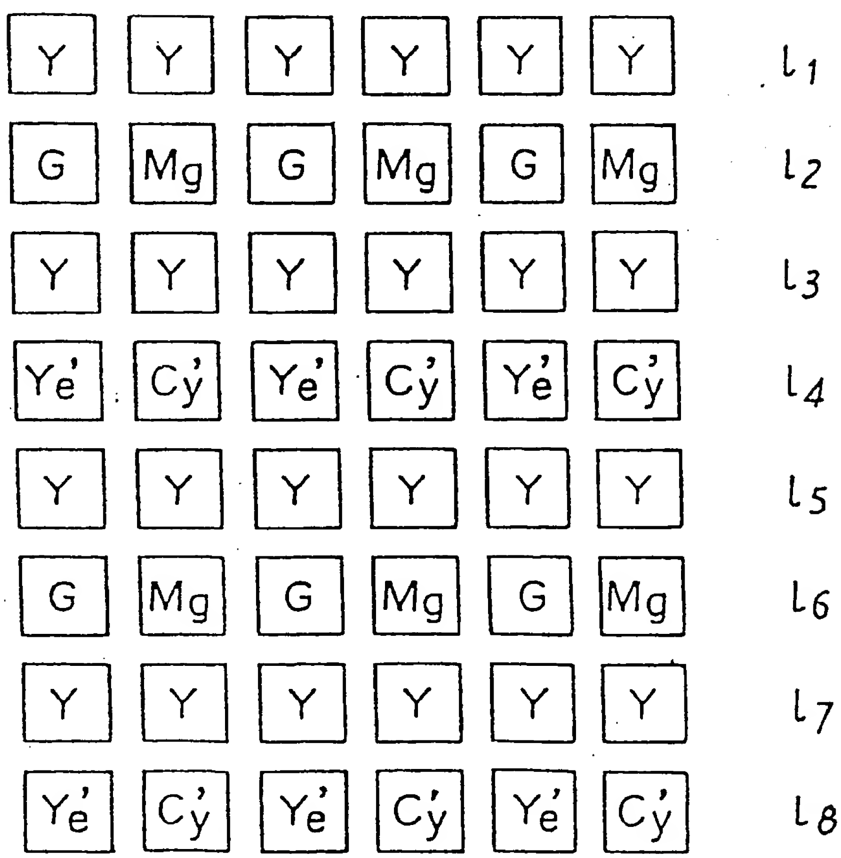
Y Y Y Y Y Y l_1
G Mg G Mg G Mg l_2
Y Y Y Y Y Y l_3
Ye' Cy' Ye' Cy' Ye' Cy' l_4
Y Y Y Y Y Y l_5
G Mg G Mg G Mg l_6
Y Y Y Y Y Y l_7
Ye' Cy' Ye' Cy' Ye' Cy' l_8

FIG. 12